DESIGN OF HEADWORK FOR LOWER NAGAVALI IRRIGATION PROJECT

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology

In

Civil Engineering

BY

BALKRISHNA PANGENI
ROLL NO: 109CE0055

DEPARTMENT OF CIVIL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY
ROURKELA 769008

MAY 2013

DESIGN OF HEADWORK FOR LOWER NAGAVALI IRRIGATION PROJECT

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology

In

Civil Engineering

BY

BALKRISHNA PANGENI
ROLL NO: 109CE0055

Under the guidance of

Prof. K.C Patra
Department of Civil Engineering
National Institute of Technology, Rourkela

DEPARTMENT OF CIVIL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY
ROURKELA 769008

MAY 2013

DEPARTMENT OF CIVIL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY
ROURKELA 769008

CERTIFICATE

This is to certify that the thesis entitled ***"Design of Headwork for Lower Nagavali Irrigation Project"*** submitted by ***Balkrishna Pangeni (Roll Number: 109CE0055)*** in partial fulfillment of the requirements for the award of ***Bachelor of Technology*** in the Department of Civil Engineering, National Institute of Technology, Rourkela is an authentic work carried out under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to elsewhere for the award of any degree.

Place: Rourkela
Date:

Prof. K.C Patra
Civil Engineering Department
National Institute of Technology, Rourkela

DEPARTMENT OF CIVIL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY

ROURKELA 769008

A C K N O W L E D G E M E N T

It gives me immense pleasure to express my deep sense of gratitude to my supervisor ***Prof. K.C. Patra*** for his invaluable guidance, motivation, constant inspiration and above all for his ever co-operating attitude that enabled me in bringing up this thesis in the present form.

I am extremely thankful to ***Prof. N. Roy***, Head of Department, and Department of Civil Engineering Department for providing all kinds of possible help and advice during the course of this work.

I am greatly thankful to Prof. **S.K. Das**, all the staff members of the department and my entire well-wishers, class mates and friends for their inspiration and help.

Place: Rourkela
Date:

Balkrishna Pangeni
B. Tech. (Roll: 109CE0055)
Civil Engineering Department
National Institute of Technology, Rourkela

ABSTRACT

This paper discuss about the design methodology of a dam and its stability against failure for a Irrigation project. Most of the people of Rayagada district has taken agriculture as their means of living and they are mostly dependent on seasonal rainfall for cultivation. This dependeny on direct rainfall water for the cultivation of crop has lead to the reduction in crop yield due to lack of rainfall.So, in this paper, I have studied the hydrological feature of the area,analysed it and a suitable section is designed considering the design flood and the discharge that can be made avaialabe at the downstream.The dam is then analysed using a software, PLAXIS for its stability and suitability.Finally, a complete profile of a ogee crested spillway is drawn.Successfull implementation of this project will facilate irrigation water for Gross Command Area(GCA) of 14,000Ha and Cultivable Command Area(CCA) of 8,500 Ha.

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 GENERAL OVERVIEW

In general,irrigation is the application of water to the soil for the purpose of supporting plant growth.[1] Dependeny on direct rainfall water for the growth of crop may lead to reduction in crop yield due to lack of rainfall. India with many large and small rivers, still faces the problem of shortage of irrigation water due to the reason that people have to depend upon the seasonal rainfall depending on the geographical location of the area. And the same river some time brings down very high flood discharge leading to drowing down large area.Thus, requirement of irrigation water is one problem and at the same time ,desingnig of dam and the canals for irrigation water supply.

The belief that large dams, by increasing irrigation and hydroelectricity production, can cause development and reduce poverty has led developing countries and international agencies such as the World Bank to undertake major investments in dam construction. By the year 2000, dams generated 19 percent of the world's electricity supply and irrigated more than 30 percent of the 271 million hectares irrigated worldwide. However, these dams also displaced over 40 million people, altered cropping patterns, and significantly increased salination and waterlogging of arable land. India, which, with over 4,000 large dams, is the world's third most prolific dam builder (after China and the United States) [2]. This is a very big number when compared to that of the word.But still due to lack of technology and proper hydrology study and prior stability analysis, some dams are found to be unsafe and many of them have failed.I have studied some of the dam that failed and have analysed the reason for their failere which led me to design a safe dam for people of Rayagada district who were in a real need of irrigation water for their living as most of the people of that area are mainly dependend in agriculture for their living and source of economy.

Kaddam Project Dam, Andhra Pradesh, India, built in Adilabad ,in 1957 - 58, the dam was a composite structure, earth fill and gravity dam. It was 30.78 m high and 3.28 m wide at its crest. Its maximum full storage was was 1.366 * 108 m^3. The observed floods were 1.47 * 104 m3/s. The dam was found to be overtopped by 46 cm of water above the crest, inspite of a free board allowance of 2.4 m, causing a breach of 137.2 m wide that occurred on the left bank and led the dam to fail in August 1985 right after one year of its construction.

The Kaila Dam in Kachch, Gujarat, India was constructed in between 1952 - 55 as an earthfill dam with a height of 23.08 m above the river bed and 213.36 m crest length. Its full reservoir level was 13.98 million m^3. The spillway was of ogee shaped and ungated. The depth of cutoff was 3.21 m below the river bed. Inspite of a freeboard allowance of 3.96 m at the maximum reservoir level the energy dissipation devices first failed and later the embankment collapsed due to the weak foundation bed in 1959.

Similarly other dams like Kodaganar Dam constructed in Tamil Nadu, Machhu II (Irrigation Scheme) Dam of Gujarat, Nanaksagar Dam of Punjab, Khadakwasla Dam of Maharashtra, India, 1864 - 1961) were found to be failed.[3] And the main reason behind their failure was found to be lack of proper hydrology analysis that resulted in excess discharge in the dam than the it was designed for and also due to improper or faulty desing and insufficient spillway.Considering these historical fact of dam failure I have given utmost important to the hydrological analysis and then stability check using reliable software, PLAXIS.I had collected the precipitation data from two stations in the area namely Kalyanisinghpur and Kashipur that affects the flood discharge in the river Nagavali.The precipitation data obtained from Kashipur station was from the year 1990-91 to 2009-10 and that of Kalyanisinghpur was from the year 1969-70 to 2009-10. The unknown rainfall were then obtained by rainfall-rainfall correlation of these stations by using suitable regression formula.

Following Hydrological and dam features were used during designing:

1.2 HYDROLOGY:

Hydrology is the study of origin, distribution and circulation of water in different forms in land and atmosphere.In my project, I was basically concerned with collection of data and determination of discharge with variation of time using hydrograph, being specific using Synders Synthetic Unit Hydrograph.

1.2.1 Hydrograph

A **hydrograph** is a graph showing the rate of flow i.e. discharge with time in a river, or other channel or conduit carrying flow.It is the total response or the output of a watershed beginning with precipitation as the hydrological exciting agent or input.A hydrograph is a result three phases namely base flow, subsurfaceand surface flow The rate of flow is usually expressed in cubic meters or cubic feet per second.

1.2.2 Unit Hydrograph

An **Unit Hydrograph (UH)** or unit graph of a watershed is defined as the hydrograph of direct runoff hydrograph resulting from a unit depth of 1 cm of excess rainfall of constant intensity generated uniformly over the basin or drainage area occurring for a specified duration of D hour.The term unit depth of rainfall excess means excess rainfall above and over all the losses (like evaporation, transpiration,interception,depression storage and depression storage) in the basin for which hydrograph is to be obtained.[4]

1.2.3 Snyder's Synthetic Unit Hydrograph

When a catchment is ungauged, the established empiracle formula or relation between the catchment characteristics and unit hydrograph parameters may be used to synthesize a unit hydrograph for a basin. A synthetic unit hydrograph has all the features of the unit hydrograph, but it does not require rainfall-runoff data. A synthetic unit hydrograph is derived from the theory and experience, and its purpose is to simulate basin diffusion by estimating the basin lag or lag time based on a certain formula or procedure. The first synthetic unit hydrograph model was developed by Snyder in 1938 [5] and is accepted as a standard practice for the derivation of a unit hydrograph for a basin where rainfall and runoff datas are not available.

1.3 EARTHEN DAM

Any hydraulic structure that supplies water to the off-taking cannel is called a headwork.Headworks my be divided into follwing two types :

1. Storage headwork.
2. Diversion headwork.

A diversion headwork is a hydraulic structure constructed to divert the required supply into the canal from the river.

A storage headwork comprises the construction of a dam across a river valley so that water can be stored during the period of excess water level in the river and release it when demand increases above the available supplies.According to the most common type of classification a dam can be classified into two types namely

1.Rigid Dams.

2.Non-Rigid Dams.

Rigid dams are those which are constructed using rigid materials like masonary,concrete,steel or timber.They are further classified as follows:

1. Solid masonary or concrete gravity dam.
2. Arched masonary or concrete dam.
3. Concrete butress dam.
4. Steel dam.
5. Timber dam.

Non-rigid dams are those which are constructed using non-rigid materials like earth and/or rockfill available near or away the site.They can be of following types:

a) 1.Earth dam.
b) 2.Rockfill dam.
c) 3.Combined earth and rockfill dam.

Earthen dams are the type of dam which are constructed using earth material available economically or locally.These are the cheapest type of dam as they utilizes the locally available materials, less skilled labour and primitive equipment.It is further divided into following three types:

i. Homogeneous Embankment type
ii. Zoned Embankment type
iii. Diaphragm type.

We had opted for Homogeneous Embankment or Homogeneous earth dam during the construction of which soil material is placed in thin layers(15 cm to 30 cm) and then compacted by using rollers.It is the simplest type of an earthen dam which consists of single material and is homogeneous throughout so it is called homogeneous type. A purely homogeneous type of dam is composed of a single kind of material. Such purely homogeneous section, has now been replaced by a modified homogeneous section in which considerable amount of pervious material is used to control the action of seepage so as to allow much steeper slopes as compared to pure homogenous dam. This type of dam is used when only one type of material is economically or locally available around the site of construction. It is also used as it is economic due to requirement of less skilled labour and primitive type of equipment during the construction.However larger dams are rarely designed as homogeneous type because of the dam being more prone to failure due to seepage and unstability. To overcome this problem, internal drainage system in the form of horizontal blanket,rock toe and/or sand chimney is constructed inside the dam.

The main components of Homogeneous Earthen dams,their brief function and basic design requrements are mentioned below;

- ***Impervious Cut off***: The cut off is located such that its centre line is within the base of impervious core and is the upstream of centre line of dam.When the depth of the pervious foundation strata is very large, a cutoff may be provided upto lesser depth.It is requred to reduce the loss of stored water through foundations and to prevent sub-surface erosion by piping of the foundation.
- ***Internal drainage system and foundations*: **The water seeping through the body of earthen dam and/or through the foundation is very harmfull as it weakens the stability of the dam causing the softening of slopes due to the development of pore water pressure.Inorder to control this seepage to a large extent,Internal drainge filters plays very important role.Such drainage filters are generally provided in the form (i) rock toe (ii) horizontal blanket and (ii) vertical or slanted sand chimney.
- ***Drainage filter*** is one of the important part in the dam construction and it should be such designe that neither embankment nor the foundation material can penetrate and clog the

filter.Terzaghi has given a rational approach to design the drainage filters which is given as,

$$\frac{D_{15}\ of\ filter}{D_{85}\ of\ base\ material} < 4\ to\ 5 < \frac{D_{15}\ of\ filter}{D_{15}\ of\ base\ material}$$

Base material here denotes the embankment soil or the foundation soil surrounding the filter.

- ***Slope protection*****:** Due to the precipitation and water level in the reserviour,scouring of the external slope surface can take place.In order to ensure this slope protection riprap is placed at the outer slope in the upstream. A minimum of 300 mm thick riprap over 150 mm thick filter layer may be generally provided upto the top of dam. In case of the downstream,slope protection is ensured by turfing or riprap turfing on the entire downstream slope from top of the dam to the toe.In addition, horizontal berms at suitable interval may be provided in case of large dam to protect from the erosion action of rain and its run-off. The details on downstream and upstream slope protection is clearly mentioned in IS 8237-1985.

1.4 STABILITY OF THE EARTHEN SLOPES

This is the most important part of this project. Designing a dam is not only of the prior importance,designing it safe against failure criterion is the main deal. The constructed dam should be safe against adverse materological condition and the geological feature of the location and the dam itself. The following stability condition were taken into consideration for analysis as mentioned below:

1. Stability of the downstream slope during steady seepage
2. Stability of the downstream slope under steady seepage from the consideration of horizontal shear at base under downstream slope of the dam.
3. Stability of the foundation against shear.
4. Overall stability of the dam section.

All these stability check were done by using most popular and reliable Analysis software, **PLAXIS**.

1.4.1 PLAXIS

PLAXIS is a finite element program designed for geotechnical applications in which soil models are used to simulate the soil behaviour. In PLAXIS, stresses and strains are calculated at individual Gaussian integration points rather than at individual nodes. The calculation stage requreis selection of analysis type such as Plastic, dynamic, consolidation and phi-c reduction. The loads assigned are activated here and analysed. In the post processing stage, plotting of curves between various calculated parameters such as load vs displacement is done. Input parameters like stiffness and poisson’s ratio of the soil influence the displacement of the slope. For stability check material properties were first defined which we had obtained from the site of construction of the dam and suitable soil material that were proposed to be used for the construction. The cross section of the dam was drawn by using coordinate, after which material properties were assigned to the dam section and the software was run to analyse the design and finally output was obtained based on the type of construction used and the phreatic line given.

1.5 SPILLWAY:

Spillway is a passage constructed over or around a dam for the effective disposal of surplus water from upstream to downstream when the reservoir itself is full. Spillways are particularly important safety features for earth dam, protecting the dam and its foundation from erosion. They may lead over the dam or a portion of it or along a channel around the dam or a conduit through it.[6] There are six major types of spillway out of which we have chosen ogee crested spillway as it is improved form of free overfall or straight drop spillway and is widely used with concrete,masonary, arch and butress dams.

******

CHAPTER 2

LITERATURE SURVEY

Xu ,Y.Q.; Unami, K. and Kawachi, T. in their paper *"Optimal hydraulic design of earth dam cross section using saturated–unsaturated seepage flow model*" formulated an optical hydraulic design problem regarding an earth dam cross section for the steady model of saturated-unsaturated seppage flows in porous media.The results showed that an inclined clay core of less hydraulic conductivity should be located on the upstream side of the cross section and unsaturated zone plays an inportant role in the flow field and the optimal design.

Tien-kuen,Hnang, in his paper "*Stability analysis of an earth dam under steady state seepage*" has described the numerical procedure for performing stability analysis of an earth dam after the filling of reserviour by using the piezometric heads at different points in an earth dam after filling the reserviour.The result was analysed and sufficient factor of safety was found against the failure of the dam. He concluded that sufficient factor of safety has to be ensured to prevent earth dam against the failure.

Abolfazl Nazari Giglou, Taher Nazari Giglou and Afshar Minaei in their paper "*Seepage through Earth Dam*" numerically analysed different homogeneous earth dams of height 5, 10, 20, 30, 40 and 50 m with a two-dimensional finite element code and they concluded that the seepage flow rate depends on earth dam permeability coefficient (K), downstream and upstream slopes and the total head (H) parameters.They also found that the rate of seepage discharge increase through the earth dam with the increase of downstream slope amplitude angle.

Rasul Daneshfaraz1, Shabnam Vakili, Mahdi Majedi-Asl and Mohammad Rostami in their research paper "*Numerical Investigation of Upstream Face Slope and Curvature of Ogee Spillway on Flow Pattern*" concluded that the change in upstream face slope of ogee spillway causes a change in discharge coefficient and discharge eventually. According to model results in three flow heights, discharge has increased 0.39%-0.76% in USBR crest and 1.2%-1.62% in the elliptical crest through making inclined upstream face.

2.2 OBJECTIVES OF THE PRESENT WORK

The main objectives of this projects are as follows:

1. To study the hydrology
2. To design the crosssection of the dam.
3. To check the stability analysis of the dam using PLAXIS software.
4. To design the Spillway Profile.

****

CHAPTER 3

STUDY AREA

3.1 INTRODUCTION

The River Nagavali is one of the main rivers of Southern Odisha and North Eastern Andhra Pradesh States in India, between Mahanadiand Godavari basins.The total catchment area is 1176 Sq. Km. The project site for Lower Nagaveli Irrigation Project is situated in Bheja vilage of Kalyanisinghpur block.It lies in Rayagada district of Orissa. The latitude of the project site is 19°-23' North and latitide 83°-21'-45'' East. Distance of the project site from state capital,Bhubaneswar is about 415 Km. Nearest rail head from the project site is at Rayagada and nearest airport is at capital Bhubaneswar.

Figure 3.1 Location of Project site

****

CHAPTER 4

METHODOLOGY

4.1 HYDROLOGY

4.1.1 Precipitation data collection:

Precipitation is that part of the atmoisture which reaches the earth's surface after condensation in different forms. The main forms of precipitation include drizzle, rain, sleet, snow and hail.In Rayagada district, atmospheric moisture causes good amount of precipitation during the month of June-October and nearly dry weather during the remaining periods.Therefore we had considered rainfall data of the month June-October for rainfall analysis and discharge measurement.The dicharge at Nagavali river is mainly influenced by the precipiation at follwing stations;

1. Kalyanisinghpur
2. Lanjigarh
3. Thumal Rampur
4. Kashipur

Rainfall data from the station Kalyanisinghpur and Kashipur were collected from the year 1969-70 to 2009-10 and 1990-91 to 2009-10 respectively.However,rainfall data of rest two stations Lanjigarh and Thumal Rampur were not available so their rainfall influence were taken to be equal to that of Kalyanisinghpur and Kashipur during the calculation of mean aerial rainfall by Thiessen Polygon.

4.1.2 Estimation of Missing data:

Failure of any rain gauge or absence of observer from a station causes short break in the record of rainfall at the station and in some case due to geographical location and unavailability or absence of raingauge cause lack of data of the station.These gaps or missing data were estimated by rainfall-rainfall correlation of the two station by regression fromula.We had considered linear variation of the data.We had obtained the correlation between the rainfall of two station by using MS-EXCEL and Coefficient of Determination (R^2) was also obtained . For a regression line to be nearly linear its coefficient of Determination value can be consider to be above 0.8.

4.1.3 Mean Aaerial Rainfall:

A rain gauge records rainfall at a geographical region and for the hydrologic analysis precipitaion has to be computed on hourly,daily,storm period,ten-day,monthly or yearly basis.There are many methods available for computation of average precipitation over the basin as mentioned below:

1. Arithmetic Average
2. Thiessen Polygon
3. Isohyetal
4. Grid point
5. Orographic

I have used Thiessen polygon method for the determination of average rainfall as it is easy and reliable methd.Advantage of this method over arithmetic mean is that,in this method weightag is given to all measuring gauges on the basis of their aerial coverage on the map,thus reducing deccrepencies in their spacing over the basin.

Procedure

1. All the gauges in and around the basin were accurately marked on a map drawn to scale as Thumal Rampur(T), Lanjigarh(L), Kashipur(KA) and Kalyanisinghpur(K).
2. Conseecutive stations were joined by straight to for triangles.

3. Perpendicular bissectors were drawn to these lines such that the bisectors formed a polygon around each stations.
4. Each stations on the map were thus enclosed by a polygon.A polygon represents an area for which the station rainfall is the representative.
5. Area of each polygon was measured by counting the unit boxes of the graph over which map was drawn.
6. Thiessen weights were computed by dividing the area of each polygon by the total basin area and checked for the sum of weights of all stations to be equal to unity.
7. The precipitation data of station Thumal Rampur,Lanjigarh were not available so their precipitation of Thumal Rampur was considered to be equal to that of nearest station Kashipur and precipitation of Lanjigarh to that of Kalyanisinghpur.
8. Finally the average precipitation was calculated by using the relation,

$$P_{av} = \frac{A_1P_1 + A_2P_2 + A_3P_3 + A_3P_3 + A_3P_4}{A_1 + A_2 + A_3 + A_4}$$

$$P_{av} = P_1W_1 + P_2W_2 + P_3W_3 + P_4W_4$$

Where P_1, P_2, P_3, P_4 represents precipitation and A_1, A_2, A_3, A_4 area of 4 stations respectively and W_1, W_2, W_3, W_4 their thiessen wight given by $\frac{A_1}{A}, \frac{A_2}{A}, \frac{A_3}{A}, \frac{A_4}{A}$.

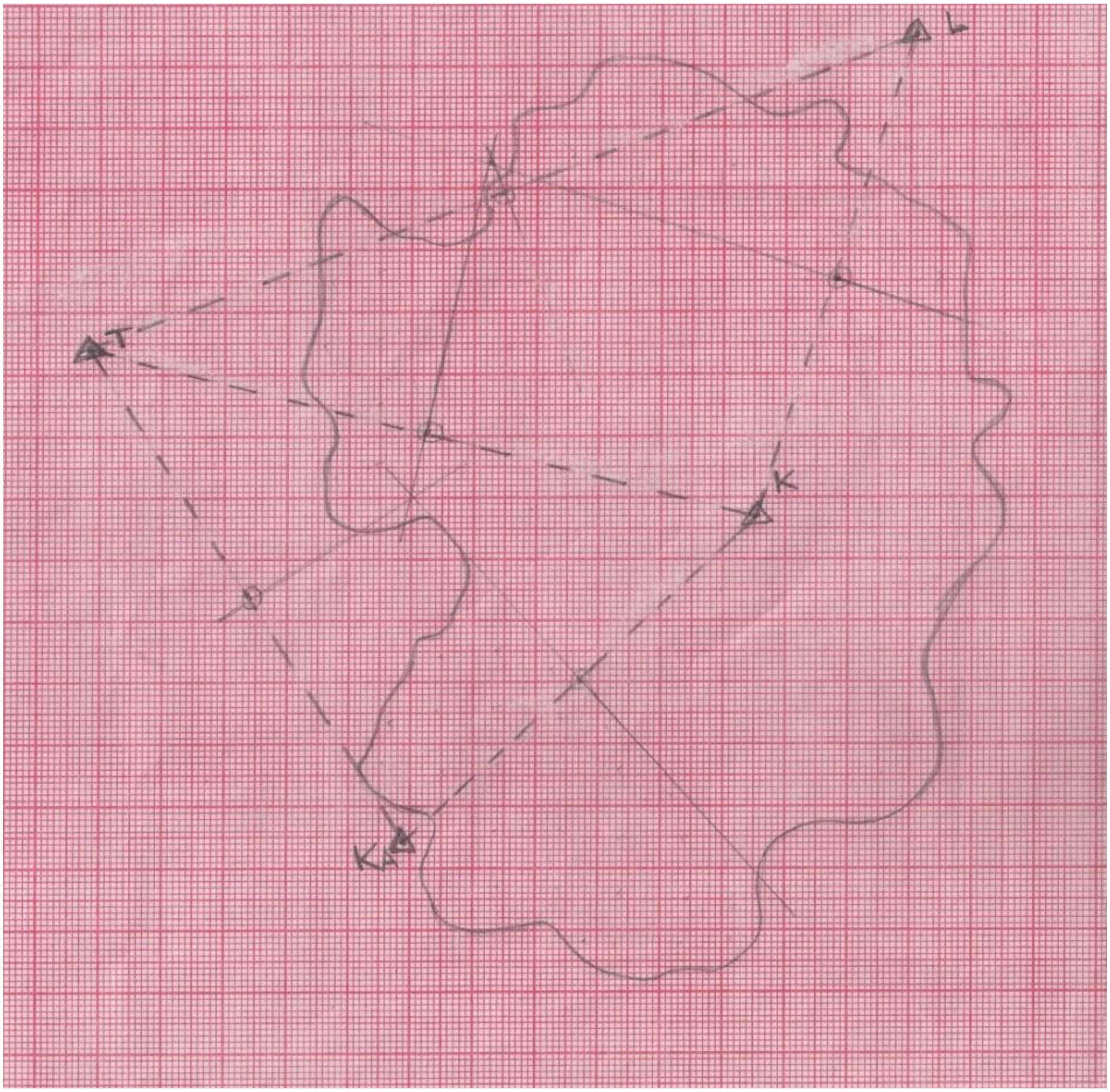

Figure 4.1 Weightage area using Thiessen Polygon

4.1.4 Synders Synthetic Unit Hydrograph

In order to obtain a unit hydrograph, Snyder gave two parameters: (i) a time parameter C_t, and (ii) a peak parameter C_p. A larger C_t meant a greater basin lag and, consequently, greater diffusion. A larger C_p meant a greater peak flow and consequently less diffusion.

Parameters of Synder's Approach:-

1. Lag time (t_p):

   It is the time from the center of rainfall – excess to the Unit Hydrograph (UH) peak and is given by

   i. $t_p = C_t (L.L_c)^{0.3}$

   where t_p = Time [in hrs];

   C_t = Coefficient,a function of watershed slope,shape and ranges between 1.35~1.6 (for steeper slope, C_t is smaller);

   L = length of the longest main channel [in km];

   L_c = length along the main channel from the gauging site to the point nearest to the watershed area centroid.

2. UH Duration (t_r):

   It is the duration of rainfall excess for a standard storm and is given by

   $$t_{re} = \frac{t_p}{5.5}$$

   where t_r and t_L are in hours. If the duration of UH is other than t_{re}, then the lag time needs to be adjusted as

$t_{np} = t_p + 0.25\ (t_r - t_{re})$

where t_{np} = adjusted lag time;

t_r = desired UH duration.

3. UH Peak Discharge (q_p):

It is the maximum discharge in the basin and is given by

$$Q_{pr} = \frac{2.78 C_P A}{tp}$$

Where, C_p = coefficient of the area for flood wave and storage condition, varying between 0.56 ~ 0.69;

A= area of the basin in km^2

Q_{pr} = Peak discharge in $m^3/s/km^2$

4. Time Base (T b):

It is the time period between the starting of the direct runoff hydrograph to the end of the runoff hydrograph due to storm and is given by,

T_b=72+3tp

This equation holds good for small catchment however in case of small catchment follwing equation propsed byTaylor and Schwartz(1952) may be followed as in case of our catchment,

T_b =5(t_{np}+ .5t_r)

where Tb is in [hrs]

5. UH Widths:

The tentative unit hydrograph is ploted by considering the following two equations proposed by US Army Corps of Engineers,

$$W_{50} = \frac{5.87}{q_{pru}^{1.08}}$$

$$W_{75} = \frac{3.354}{q_{pru}^{1.08}}$$

Where $q_{pru} = \frac{Q_{pr}}{A}$ is the peak discharge per unit drainage area in $m^3/s/km^2$

W_{50} and W_{75} are in hours; Usually, 1/3 of the width of W_{50} and W_{75} is distributed before UH peak and 2/3 after the peak

The volume of UH was checked to be close to 1 cm x area of the catchment in km^2.The coordinate of the UH was adjusted to make 1 cm x area of the catchment in km^2.

4.1.5 Flood Estimation using Unit Hydrograph:

The ordinates obtained from the 1 hour unit hydrograph(using Synders synthetic unit hydrograph) were tabulated alongwith the respective Time. Rainfall excess was made available from the preliminary report on “Lower Nagavali Irrigation project” by Prof. K.C.Patra,NIT Rourkela. Surface-Runoff was obtained by multiplying the coordinates with the various rainfall excess.A base flow of 58.84 cumes at the rate of 0.005cumec/sq km was added to the sum of Direct Runoff Hydrograph(DRH) obtained i.e. Surface Runoff.Finally total Runnoff was obtained by adding surface runoff and base flow, and the maximum runoff was taken as design flood discharge.

4.2 DAM DESIGNING:

Dam designing is the most important for any irrigation project.Surveying result as mentioned on the project report “Project report of Lower Nagavali Irrigation Project”, by Prof. K.C. Patra were taken as the main source for the designing.The RL of the river bed at the site was reported to be 251.5 m and RL of Maximum Water Level(MWL) 300 m. Considering the maximam flood discharge in the river Nagavali and IS Code recommendation **(IS 8826 : 1978 Guidelines for design of large earth and rockfill dams)** for top width,free board, u/s and d/s slopes, drainage arrangement, etc, preliminary design was selected/drawn and then stability analysis using PLAXIS software was done.

AUTOCAD 2013 was used for drawing the design as it is the most popular and userfriendly for designing.

4.3 ANALYSIS:

Analysis of the designed dam was done by using PLAXIS. A two-stage dam constructed is taken.Analysis for steady seepage was done.

PROCEDURE:

- INPUT STAGE

1. Section of the dam was designed by using coordinate.

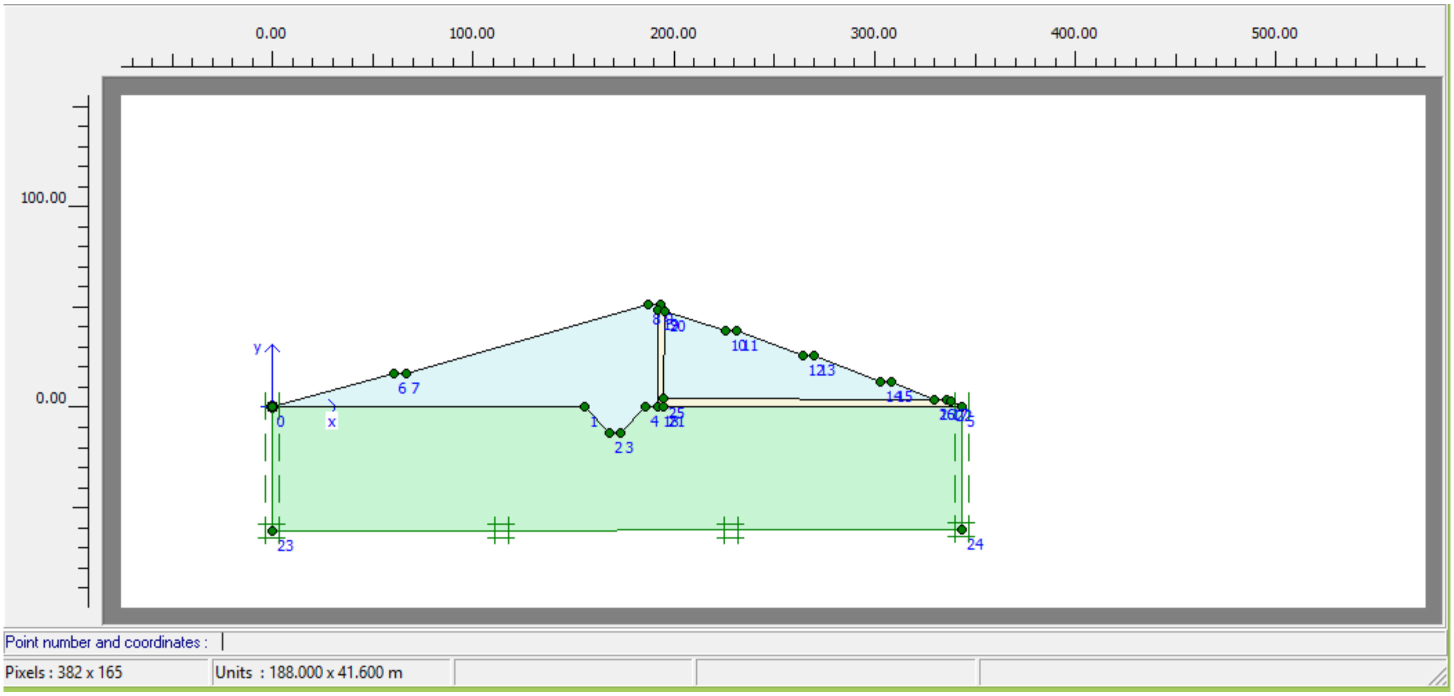

Figure 4.2 Section of dam

2. Material Property was assigned to the different components.

Table 4.1 Material property used

Mohr-Coulomb		**1** **Foundation**	**2** **Dam**	**3** **Sand**
Type		Drained	Drained	Drained
γ_{unsat}	[kN/m³]	15.89	17.20	15.00
γ_{sat}	[kN/m³]	18.00	21.00	18.50
k_x	[m/day]	0.001	0.009	1.000
k_y	[m/day]	0.001	0.009	1.000
e_{init}	[-]	0.500	0.500	0.500

Mohr-Coulomb		1 Foundation	2 Dam	3 Sand
c_k	[-]	1E15	1E15	1E15
E_{ref}	[kN/m²]	50000.000	20000.000	20000.000
ν	[-]	0.300	0.300	0.300
G_{ref}	[kN/m²]	19230.769	7692.308	7692.308
E_{oed}	[kN/m²]	67307.692	26923.077	26923.077
c_{ref}	[kN/m²]	32.00	38.00	2.00
φ	[°]	15.83	12.45	35.00
ψ	[°]	0.00	0.00	0.00
E_{inc}	[kN/m²/m]	0.00	0.00	0.00
y_{ref}	[m]	0.000	0.000	0.000
$c_{increment}$	[kN/m²/m]	0.00	0.00	0.00
$T_{str.}$	[kN/m²]	0.00	0.00	0.00
$R_{inter.}$	[-]	1.00	1.00	1.00
Interface permeability		Neutral	Neutral	Neutral

3. Mess Generation.

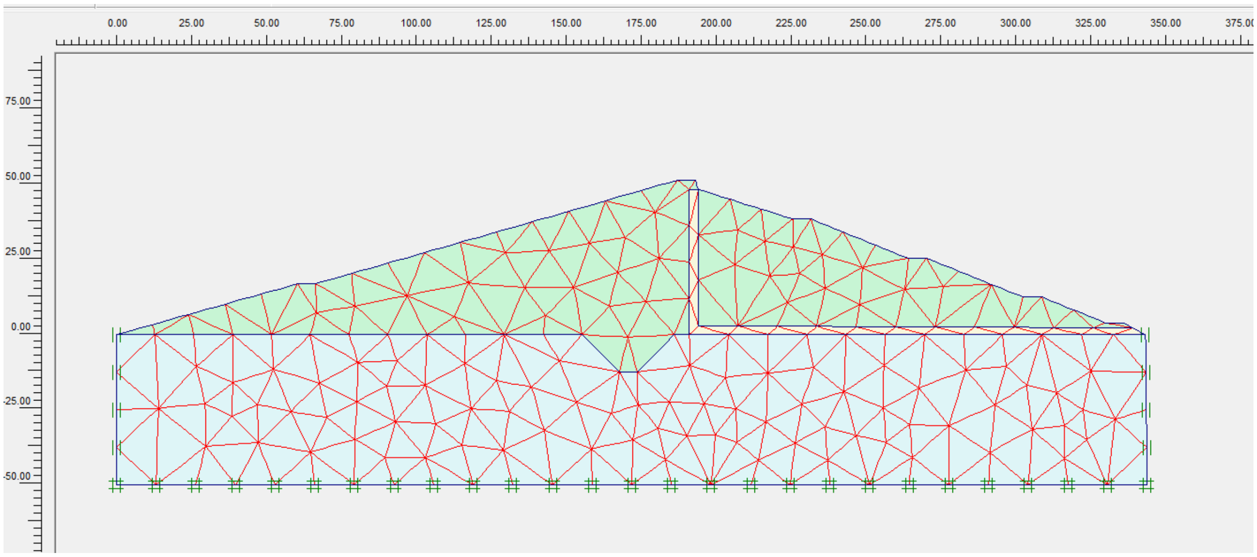

Figure 4.3 Mess generation.

4. Phreatic line was drawn on the dam section.

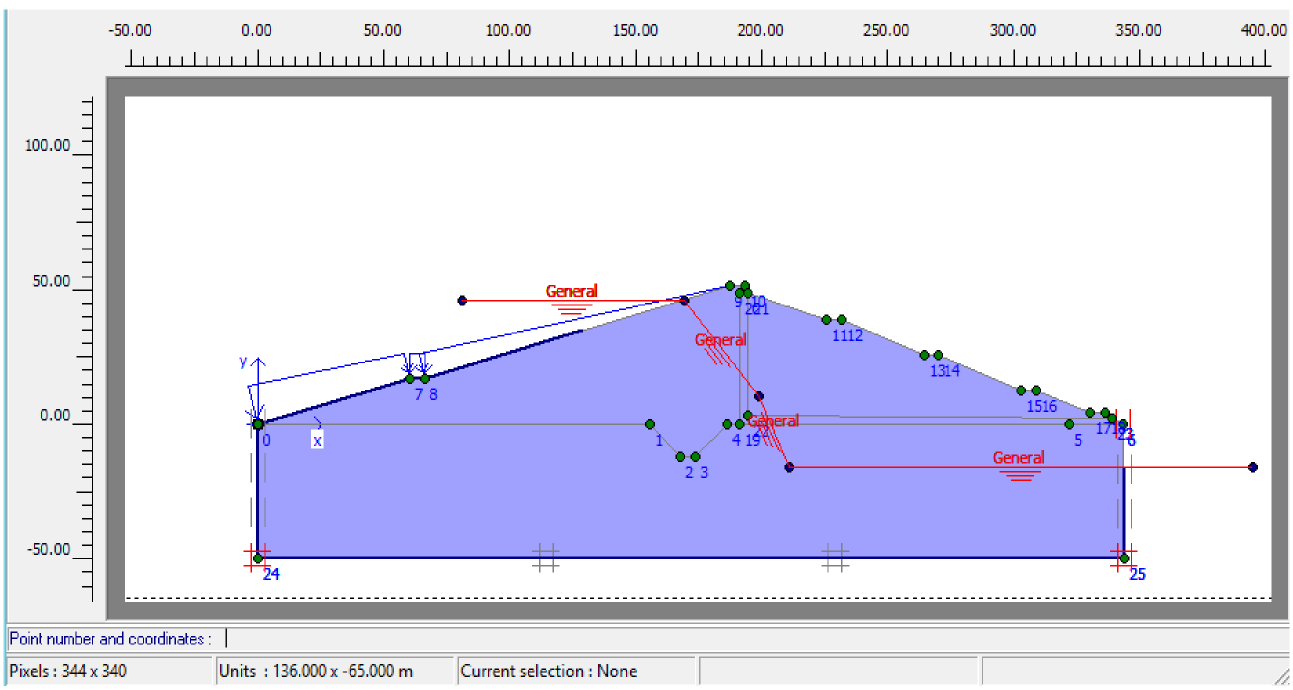

Figure 4.4 Phreatic line.

➢ CALCULATION STAGE

1. First stage of calculation was done as Plastic.
2. Second and Final stage of calculation as phi-c reduction.

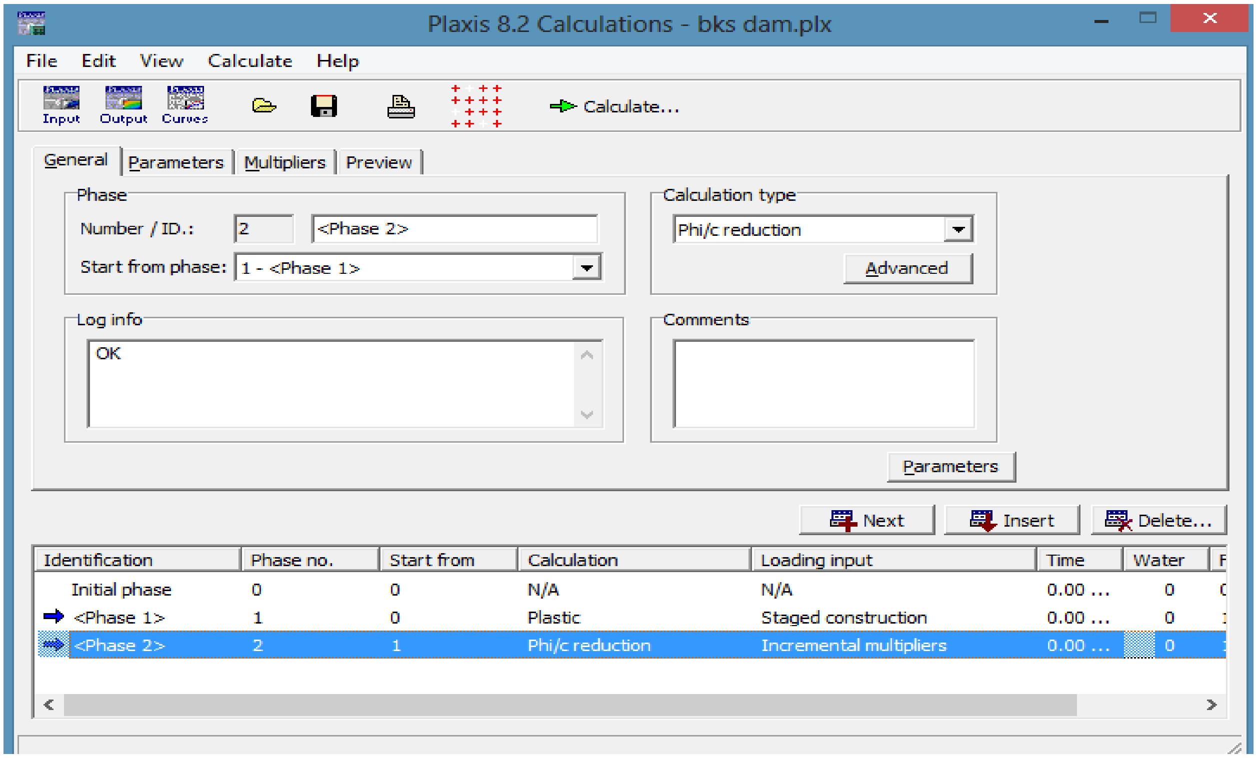

Figure 4.5 Different calculation stage

➢ POST PROCESSING

In the post processing stage, plotting of curves between various calculated parameters such as vertical strain,shear stress,active pore water pressure,etc were obtained.It is the output of the analysis.

4.4 SPILLWAY DESIGN:

The profile of the spillway was designed considering the discharge and the Maximum flood level.

Discharge of Ogee rested spillway is given as,

$$Q = C.L_e H_e^{3/2}$$

Where, C=Coeffecient of discharge

Le=Effective length of spillway crest=120m

He=Head over the crest including velocity head and Q=Discharge

Dowstream profile:

The upstream of the spillway was asumed to be vertical and downstream face parabolic and using WES formula,the downstream crest profile was drawan by finding the coordinate as given by,

$$x^{1.85} = 2 * H_d^{0.85} * y$$

The downstream face slope was assumed to be 0.7H:1V

Upstream profile:The upstream profile was drawn by finding the coordinate using the following formula given by U.S.Army corps,

$$Y=\frac{0.724(x+.27H_d)^{1.85}}{H_d} + 0.126H_d - 0.4315{H_d}^{0.375}(x + 0.27H_d)^{0.625}$$

Where x=-0.27H_d

Final profile was drawn in graph by using the coordinate of upstream and downstream and was extended to the base of the dam to give complete spillway profile.

****

CHAPTER 5

RESULTS AND CALCULATIONS

5.1 HYDROLOGY

5.1.1 Estimation of missing rainfall data:

The missing rainfall data were estimated by rainfall-rainfall correlation of the two station by regression fromula in MS-EXCEL.

Table 5.1 Rainfall data of Kalyanisinghpur(in mm)

Year	June	July	August	September	October
1969-70	161	420	152	126	27
1970-71	334	324	371	202	21
1971-72	216	192	278	168	151
1972-73	191	186	165	595	56
1973-74	50	404	289	83	136
1974-75	225	164	82	147	75
1975-76	328	223	242	197	40
1976-77	183	382	313	121	19
1977-78	160	528	195	268	28
1978-79	117	320	454	48	4
1979-80	270	132	117	108	37
1980-81	310	272	130	270	47
1981-82	106	148	358	380	7

1982-83	118	470	504	70	62
1983-84	78	164	384	414	82
1984-85	268	314	213	87	60
1985-86	215	205	334	152	60
1986-87	212	324	138	29	108
1987-88	30	177	137	120	148
1988-89	204	222	340	175	65
1989-90	397	234	282	101	10
1990-91	181	270	279	156	260
1991-92	131	561	421	175	78
1992-93	264	770	286	209	30
1993-94	169	272	136	206	48
1994-95	269	327	334	381	97
1995-96	82	331	180	155	18
1996-97	136	280	302	74	32
1997-98	181	240	357	182	17
1998-99	162	416	298	254	81
1999-00	164	172	152	239	51
2000-01	134	359	242	33	2
2001-02	375	312	220	143	32
2002-03	199	87	287	121	60
2003-04	133	311	269	218	106

2004-05	145	276	355	129	136
2005-06	153	213	95	343	210
2006-07	246	474	595	385	12
2007-08	357	314	666	280	56
2008-09	226	215	365	417	63
2009-10	115	651	329	184	34

Table 5.2: Rainfall data of Kashipur(in mm)

Year	June	July	August	September	October
1990-91	317	389	621	189	253
1991-92	148	1262	1220	239	126
1992-93	614	924	650	345	82
1993-94	281	395	296	335	101
1994-95	634	565	839	844	137
1995-96	253	578	346	187	68
1996-97	171	418	709	111	85
1997-98	317	312	939	260	66
1998-99	262	873	695	505	127
1999-00	267	199	308	451	104
2000-01	152	495	531	183	24
2001-02	354	729	372	192	73
2002-03	149	198	585	77	129

2003-04	98	409	397	409	217
2004-05	459	302	747	177	103
2005-06	179	369	293	533	230
2006-07	242	968	1027	746	3
2007-08	371	306	698	420	95
2008-09	356	227	652	403	56
2009-10	30	849	814	145	152

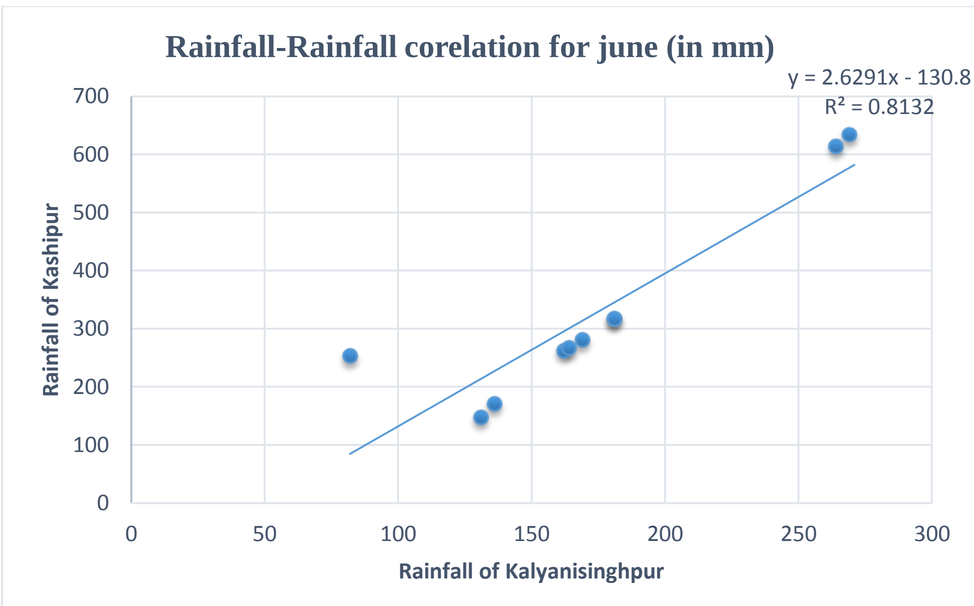

Figure 5.1 Rainfall-Rainfall corelation for June(in mm)

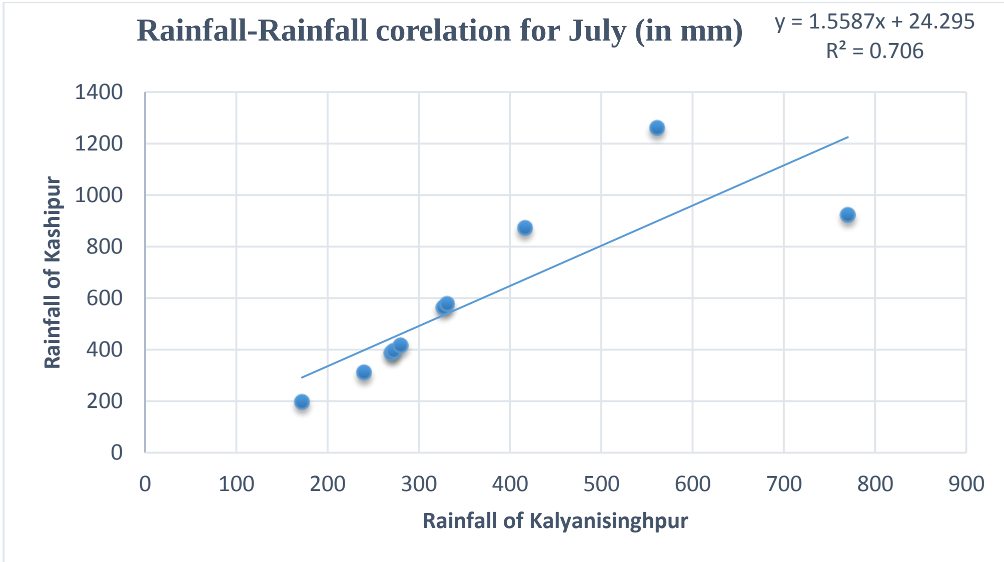

Figure 5.2 Rainfall-Rainfall corelation for July (in mm)

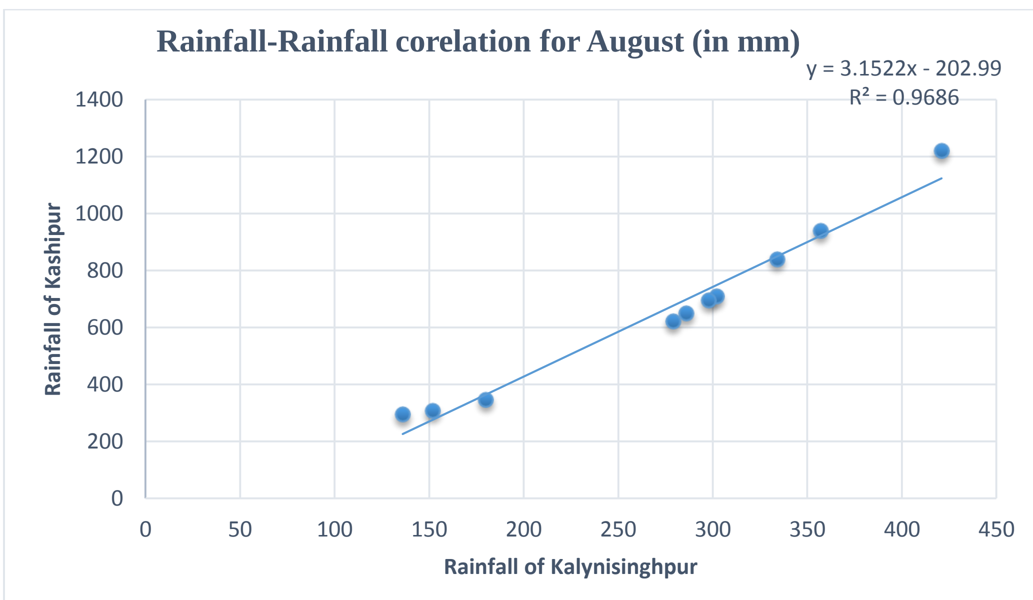

Figure 5.3 Rainfall-Rainfall corelation for August (in mm)

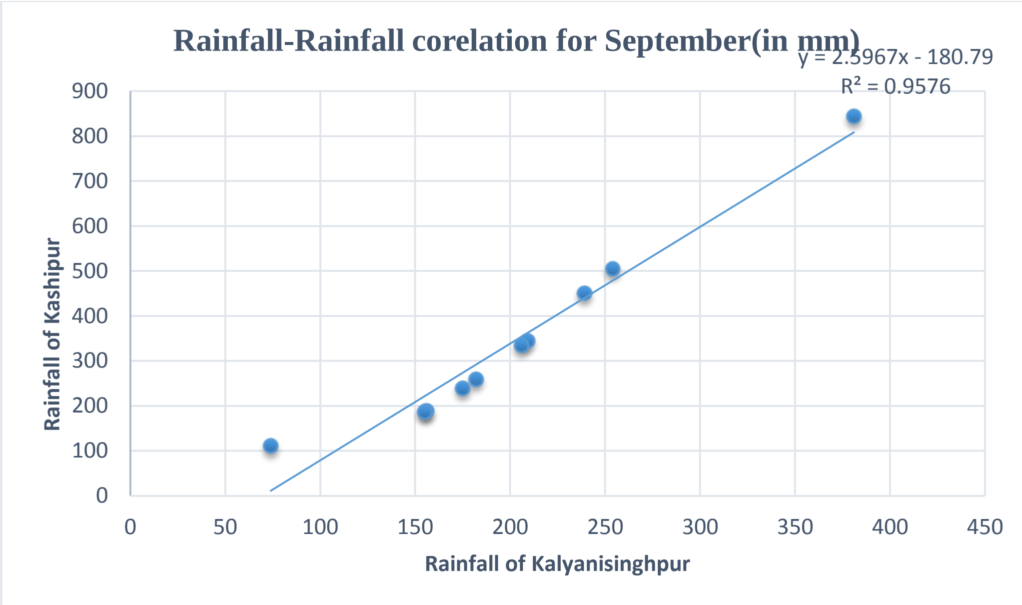

Figure 5.4 Rainfall-Rainfall corelation for September (in mm)

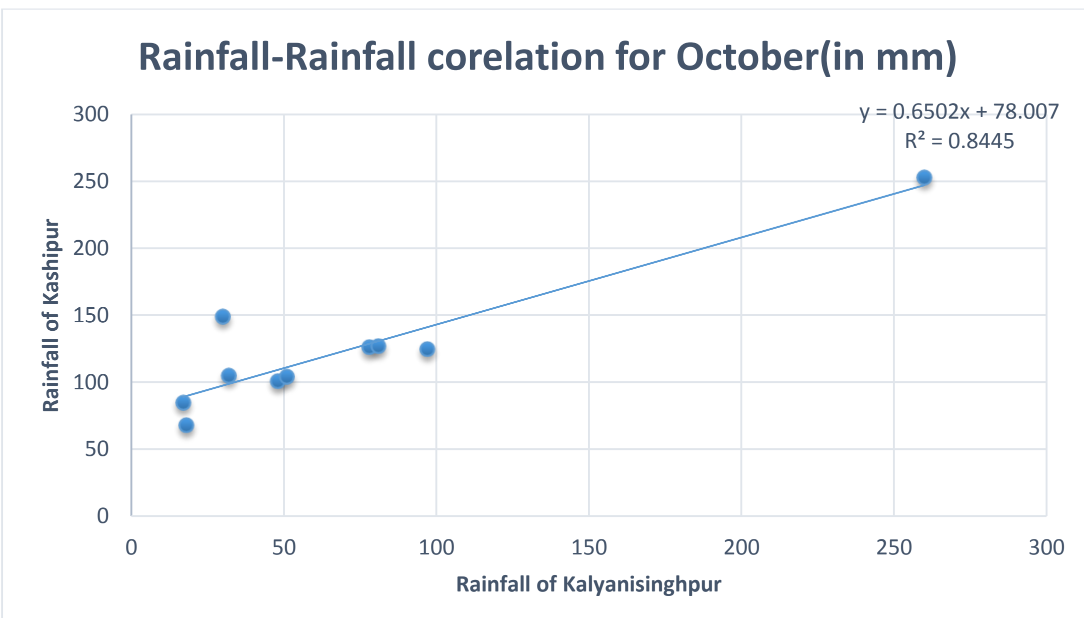

Figure 5.5 Rainfall-Rainfall corelation for October (in mm)

Table 5.3 Final Rainfall data of Kashipur including estimated rainfall.

Year	June	July	August	September	October
1969-70	255	679	276	146	82
1970-71	971	529	966	344	77
1971-72	427	324	673	255	175
1972-73	347	314	317	1364	103
1973-74	66	654	708	35	164
1974-75	457	280	55	201	118
1975-76	940	372	560	331	91
1976-77	323	620	784	133	75
1977-78	254	847	412	515	82
1978-79	83	523	1228	6	64
1979-80	639	230	166	100	89
1980-81	847	448	207	520	97
1981-82	21	255	925	806	66
1982-83	89	757	1386	1	108
1983-84	54	280	1007	894	123
1984-85	630	514	468	45	106
1985-86	422	344	850	214	106
1986-87	411	529	232	5	143
1987-88	21	300	229	131	173
1988-89	386	370	869	274	110
1989-90	1222	389	686	81	69
1990-91	317	389	621	189	253
1991-92	148	1262	1220	239	126

1992-93	614	924	650	345	82
1993-94	281	395	296	335	101
1994-95	634	565	839	844	137
1995-96	253	578	346	187	68
1996-97	171	418	709	111	85
1997-98	317	312	939	260	66
1998-99	262	873	695	505	127
1999-00	267	199	308	451	104
2000-01	152	495	531	183	24
2001-02	354	729	372	192	73
2002-03	149	198	585	77	129
2003-04	98	409	397	409	217
2004-05	459	302	747	177	103
2005-06	179	369	293	533	230
2006-07	242	968	1027	746	3
2007-08	371	306	698	420	95
2008-09	356	227	652	403	56
2009-10	30	849	814	145	152

5.1.2 Mean Aerial Rainfall:

Using thiessen polygon method mean precipitation was obtained.

Influence factor or Thiessen weight for Kalyanisinghpur and Lanjigarh = 0.591+0.132= 0.723

Thiessen weight for Kashipur and Thumal Rampur =0.2045+0.072= 0.2765

This thiessen weight was used to compute the mean aerial rainfall.

Table 5.4 Mean Monthly Rainfall (in mm)

Year	June	July	August	September	October
1969-70	187	491	186	131	42
1970-71	510	381	535	241	36
1971-72	274	228	387	192	158
1972-73	234	221	207	807	69
1973-74	54	473	405	70	144
1974-75	289	196	74	162	87
1975-76	497	264	330	234	54
1976-77	222	448	443	124	34
1977-78	186	616	255	336	43
1978-79	108	376	668	36	21
1979-80	372	159	130	106	51
1980-81	458	321	151	339	61
1981-82	82	178	515	498	23
1982-83	110	549	748	51	75
1983-84	71	196	556	547	93
1984-85	368	369	283	75	73
1985-86	272	243	477	169	73
1986-87	267	381	164	22	118
1987-88	27	211	162	123	155
1988-89	254	263	486	202	77
1989-90	625	277	394	95	26
1990-91	219	303	373	165	258
1991-92	136	755	642	193	91

1992-93	361	812	387	246	44
1993-94	200	306	180	242	63
1994-95	370	393	473	509	108
1995-96	129	399	226	164	32
1996-97	146	318	414	84	47
1997-98	219	260	518	203	31
1998-99	190	542	408	323	94
1999-00	192	179	195	297	66
2000-01	139	396	322	74	8
2001-02	369	427	262	156	43
2002-03	185	118	369	109	79
2003-04	123	338	304	271	137
2004-05	232	283	463	142	127
2005-06	160	256	150	395	215
2006-07	245	610	714	485	10
2007-08	361	312	675	319	67
2008-09	262	218	444	413	61
2009-10	91	705	463	173	67

5.1.3 Synthetic Unit Hydrograph:

Catchment Area= 1176 sq. km

L=78 km

Lc= 31.76 km

C_t for the catchment =1.35

Lag Time, t_p:-

$t_p = C_t (L.L_c)^{0.3}$ =14.077 hours

Duration of Rainfall excess, t_{re}:-

$t_{re} = t_p / 5.5$ =2.56<4 hours.

Modified lag time taking duration of rainfall excess, t_r = 4 hours

$t_{np} = t_p + 0.25 (t_r - t_{re})$ =14.437 hours

Peak Discharge:-

$$Q_{pr} = \frac{2.78 C_P A}{tp}$$

= (2.78 x .56 x 1176)/14.437

=126.81cumecs.

Time base:-

T_b =5(t_{np}+ .5t_r) = 79.68 hours

UH Widths:-

$W_{50} = \frac{5.87}{q_{pru}^{1.08}}$ = 65.05 ; ($q_{pru} = \frac{Q_{pr}}{A}$ =0.107)

$W_{75} = \frac{3.354}{q_{pru}^{1.08}}$= 37.17

Usually, 1/3 of the width is distributed before UH peak and 2/3 after the peak. The volume of

UH was checked and was corrected to be close to 1 cm 1 cm x area of the catchment in km^2.

Thus from the above equations the synthetic unit hydrograph was drawn as shown below.

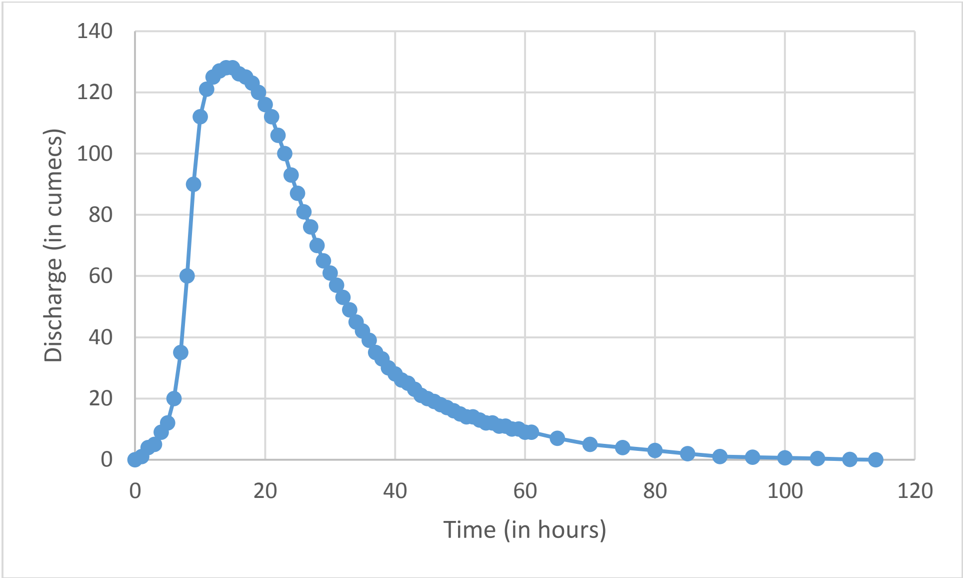

Figure 5.6 Syntheti Unit Hydrograph

5.1.4 Flood Hydrograph or Design Flood:

Time	Discharge Ordinate	RAINFALL EXCESS(mms/cms)																								Surface Runoff	Base Flow @0.05 cum/sq km	Total Runoff
		9.68	9.68	9.69	9.69	9.69	9.69	15.03	15.03	15.04	15.04	15.04	15.04	25.72	25.72	36.41	121.92	47.09	25.72	25.72	15.03	9.69	9.69	9.68	9.68			
		0.97	0.97	0.97	0.97	0.97	0.97	1.5	1.5	1.5	1.5	1.5	1.5	2.57	2.57	3.64	12.19	4.71	2.57	2.57	1.5	0.97	0.97	0.97	0.97			
0	0	0																								0	58.84	59
1	1	1	0																							1	58.84	60
2	4	4	1	0																						5	58.84	64
3	5	5	4	1	0																					10	58.84	69
4	9	9	5	4	1	0																				18	58.84	77
5	12	12	9	5	4	1	0																			30	58.84	89
6	20	19	12	9	5	4	1	0																		49	58.84	108
7	35	34	19	12	9	5	4	2	0																	84	58.84	143
8	60	58	34	19	12	9	5	6	2	0																144	58.84	203
9	90	87	58	34	19	12	9	8	6	2	0															234	58.84	293
10	117	113	87	58	34	19	12	14	8	6	2	0														352	58.84	411
11	121	117	113	87	58	34	19	18	14	8	6	2	0													476	58.84	534
12	125	121	117	113	87	58	34	30	18	14	8	6	2	0												607	58.84	666
13	127	123	121	117	113	87	58	53	30	18	14	8	6	3	0											750	58.84	809
14	128	124	123	121	117	113	87	90	53	30	18	14	8	10	3	0										911	58.84	969
15	128	124	124	123	121	117	113	135	90	53	30	18	14	13	10	4	0									1089	58.84	1148
16	126	122	124	124	123	121	117	176	135	90	53	30	18	23	13	15	12	0								1296	58.84	1355
17	123	119	122	124	124	123	121	182	176	135	90	53	30	31	23	18	49	5	0							1525	58.84	1584
18	121	117	119	122	124	124	123	188	182	176	135	90	53	51	31	33	61	19	3	0						1751	58.84	1810
19	120	116	117	119	122	124	124	191	188	182	176	135	90	90	51	44	110	24	10	3	0					2016	58.84	2075
20	116	112	116	117	119	122	124	192	191	188	182	176	135	154	90	73	146	42	13	10	2	0				2306	58.84	2365
21	112	108	112	116	117	119	122	192	192	191	188	182	176	231	154	127	244	57	23	13	6	1	0			2674	58.84	2733
22	106	103	108	112	116	117	119	189	192	193	191	188	182	301	231	218	427	94	31	23	8	4	1	0		3150	58.84	3208
23	100	97	103	109	112	116	117	185	189	193	193	191	188	311	301	328	732	165	51	31	14	5	4	1	0	3734	58.84	3793
24	95	92	97	103	109	112	116	182	185	190	193	193	191	322	311	426	1097	283	90	51	18	9	5	4	1	4377	58.84	4436
25	90	87	92	97	103	109	112	180	182	185	190	193	193	327	322	441	1426	424	154	90	30	12	9	5	4	4964	58.84	5023
26	81	78	87	92	97	103	109	174	180	182	185	190	193	329	327	455	1475	551	231	154	53	19	12	9	5	5290	58.84	5348
27	77	75	78	87	92	97	103	168	174	180	182	185	190	329	329	462	1524	570	301	231	90	34	19	12	9	5522	58.84	5581
28	73	71	75	78	87	92	97	159	168	174	180	182	185	324	329	466	1548	589	311	301	135	58	34	19	12	5676	58.84	5735
29	70	68	71	75	78	87	92	150	159	168	174	180	182	316	324	466	1561	598	322	311	176	87	58	34	19	5758	58.84	5817
30	65	63	68	71	75	78	87	143	150	159	168	174	180	311	316	459	1561	603	327	322	182	113	87	58	34	5790	58.84	5849
31	59	57	63	68	71	75	78	135	143	150	159	168	174	309	311	448	1536	603	329	327	188	117	113	87	58	5769	58.84	5828
32	55	53	57	63	68	71	75	122	135	143	150	159	168	298	309	441	1500	593	329	329	191	121	117	113	87	5693	58.84	5752
33	50	48	53	57	63	68	71	116	122	135	143	150	159	288	298	437	1475	579	324	329	192	123	121	117	113	5584	58.84	5643
34	45	44	48	53	57	63	68	110	116	122	135	143	150	273	288	422	1463	570	316	324	192	124	123	121	117	5443	58.84	5502
35	42	41	44	48	53	57	63	105	110	116	122	135	143	257	273	408	1414	565	311	316	189	124	124	123	121	5263	58.84	5322
36	39	38	41	44	48	53	57	98	105	110	116	122	135	244	257	386	1366	546	309	311	185	122	124	124	123	5064	58.84	5122
37	35	34	38	41	44	48	53	89	98	105	110	116	122	231	244	364	1292	527	298	309	182	119	122	124	124	4834	58.84	4893
38	33	32	34	38	41	44	48	83	89	98	105	110	116	208	231	346	1219	499	288	298	180	117	119	122	124	4589	58.84	4648
39	30	29	32	34	38	41	44	75	83	89	98	105	110	198	208	328	1158	471	273	288	174	116	117	119	122	4349	58.84	4408
40	29	28	29	32	34	38	41	68	75	83	89	98	105	188	198	295	1097	447	257	273	168	112	116	117	119	4107	58.84	4166
41	26	25	28	29	32	34	38	63	68	75	83	89	98	180	188	280	988	424	244	257	159	109	112	116	117	3836	58.84	3895
42	25	24	25	28	29	32	34	59	63	68	75	83	89	167	180	266	939	381	231	244	150	103	109	112	116	3608	58.84	3666
43	23	22	24	25	28	29	32	53	59	63	68	75	83	152	167	255	890	363	208	231	143	97	103	108	112	3390	58.84	3449
44	21	20	22	24	25	28	29	50	53	59	63	68	75	141	152	237	853	344	198	208	135	92	97	103	108	3185	58.84	3244
45	20	19	20	22	24	25	28	45	50	53	59	63	68	129	141	215	792	330	188	198	122	87	92	97	103	2970	58.84	3028
46	19	18	19	20	22	24	25	44	45	50	53	59	63	116	129	200	719	306	180	188	116	78	87	92	97	2751	58.84	2809
47	18	17	18	19	20	22	24	39	44	45	50	53	59	108	116	182	671	278	167	180	110	75	78	87	92	2554	58.84	2613
48	17	16	17	18	19	20	22	38	39	44	45	50	53	100	108	164	610	259	152	167	105	71	75	78	87	2358	58.84	2417
49	16	15	16	17	18	19	20	35	38	39	44	45	50	90	100	153	549	235	141	152	98	68	71	75	78	2167	58.84	2226
50	15	15	15	16	17	18	19	32	35	38	39	44	45	85	90	142	512	212	129	141	89	63	68	71	75	2009	58.84	2068
51	14	14	15	16	16	17	18	30	32	35	38	39	44	77	85	127	475	198	116	129	83	57	63	68	71	1861	58.84	1920
52	14	14	14	15	16	16	17	29	30	32	35	38	39	75	77	120	427	184	108	116	75	53	57	63	68	1715	58.84	1774
53	13	13	14	14	15	16	16	27	29	30	32	35	38	67	75	109	402	165	100	108	68	48	53	57	63	1591	58.84	1650
54	12	12	13	14	14	15	16	26	27	29	30	32	35	64	67	106	366	155	90	100	63	44	48	53	57	1473	58.84	1531
55	12	12	12	13	14	14	15	24	26	27	29	30	32	59	64	95	354	141	85	90	59	41	44	48	53	1377	58.84	1436
56	11	11	12	12	13	14	14	23	24	26	27	29	30	54	59	91	317	137	77	85	53	38	41	44	48	1274	58.84	1333
57	11	11	11	12	12	13	14	21	23	24	26	27	29	51	54	84	305	122	75	77	50	34	38	41	44	1193	58.84	1252
58	10	10	11	11	12	12	13	21	21	23	24	26	27	49	51	76	280	118	67	75	45	32	34	38	41	1114	58.84	1173
59	10	10	10	11	11	12	12	20	21	21	23	24	26	46	49	73	256	108	64	67	44	29	32	34	38	1038	58.84	1096
60	9	9	10	10	11	11	12	18	20	21	21	23	24	44	46	69	244	99	59	64	39	28	29	32	34	975	58.84	1034
61	9	9	9	10	10	11	11	18	18	20	21	21	23	41	44	66	232	94	54	59	38	25	28	29	32	920	58.84	979

		0	9	9	10	10	11	17	18	18	20	21	21	39	41	62	219	89	51	54	35	24	25	28	29	859	58.84	918
			0	9	9	10	10	17	17	18	18	20	21	36	39	58	207	85	49	51	32	22	24	25	28	803	58.84	862
				0	9	9	10	15	17	17	18	18	20	36	36	55	195	80	46	49	30	20	22	24	25	750	58.84	809
					0	9	9	15	15	17	17	18	18	33	36	51	183	75	44	46	29	19	20	22	24	700	58.84	759
						0	9	14	15	15	17	17	18	31	33	51	171	71	41	44	27	18	19	20	22	652	58.84	711
							0	14	14	15	15	17	17	31	31	47	171	66	39	41	26	17	18	19	20	617	58.84	676
								0	14	14	15	15	17	28	31	44	158	66	36	39	24	16	17	18	19	571	58.84	630
									0	14	14	15	15	28	28	44	146	61	36	36	23	16	16	17	18	527	58.84	586
										0	14	14	15	26	28	40	146	57	33	36	21	15	16	16	17	493	58.84	552
											0	14	14	26	26	40	134	57	31	33	21	14	15	15	16	455	58.84	513
												0	14	23	26	36	134	52	31	31	20	14	14	15	15	423	58.84	482
													0	23	23	36	122	52	28	31	18	13	14	14	15	388	58.84	447
														0	23	33	122	47	28	28	18	12	13	14	14	351	58.84	410
															0	33	110	47	26	28	17	12	12	13	14	310	58.84	368
																0	110	42	26	26	17	11	12	12	13	267	58.84	325
																	0	42	23	26	15	11	11	12	12	151	58.84	210
																		0	23	23	15	10	11	11	12	104	58.84	163
																			0	23	14	10	10	11	11	77	58.84	136
																				0	14	9	10	10	11	52	58.84	111
																					0	9	9	10	10	37	58.84	96
																						0	9	9	10	27	58.84	86
																							0	9	9	17	58.84	76
																								0	9	9	58.84	68
																									0	0	58.84	59
																										0		0

5.2 Cross-section of Dam:

Considering the recommendation of **IS 8826 : 1978 Guidelines for design of large earth and rockfill dams** and Geotechnical properties crossection of dam was designed.

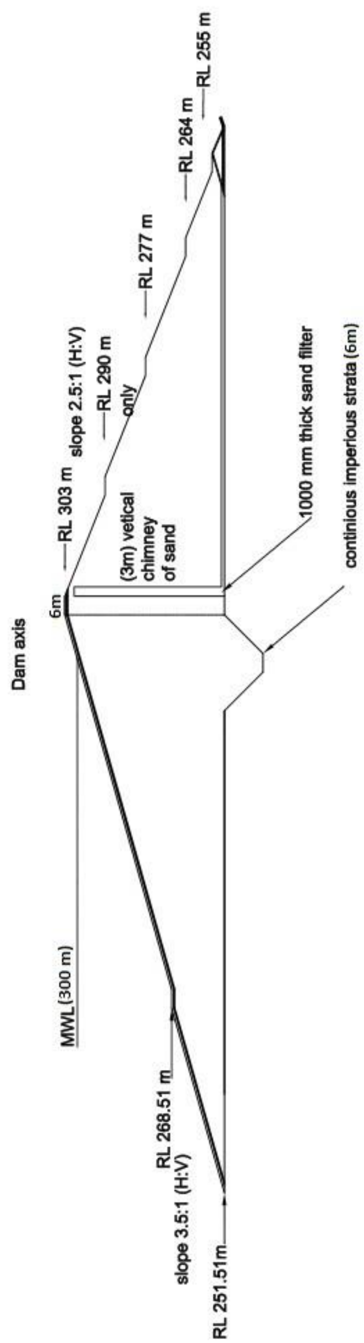

Fig. Cross section of Dam

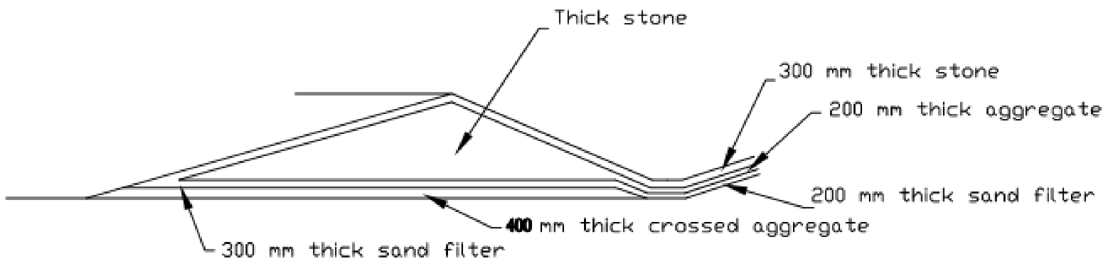

Fig. Rock Toe

5.3 ANALYSIS OF DAM:

Following results were obtained as the result of postprocessing.

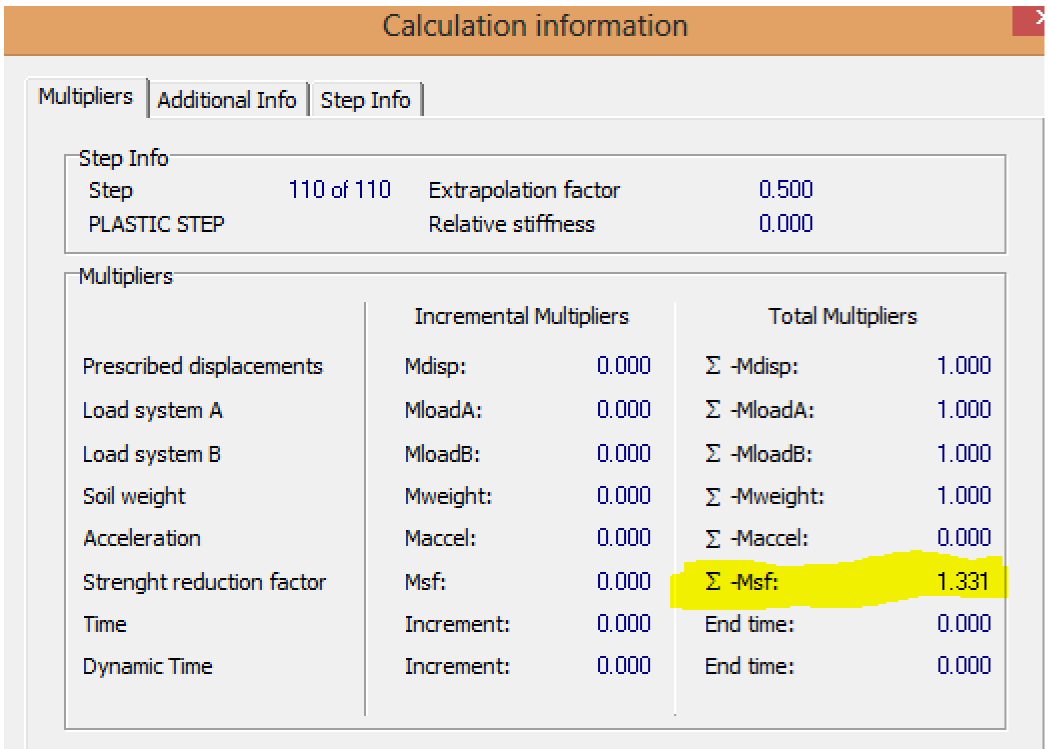

Figure 5.9 Safety factor of the design

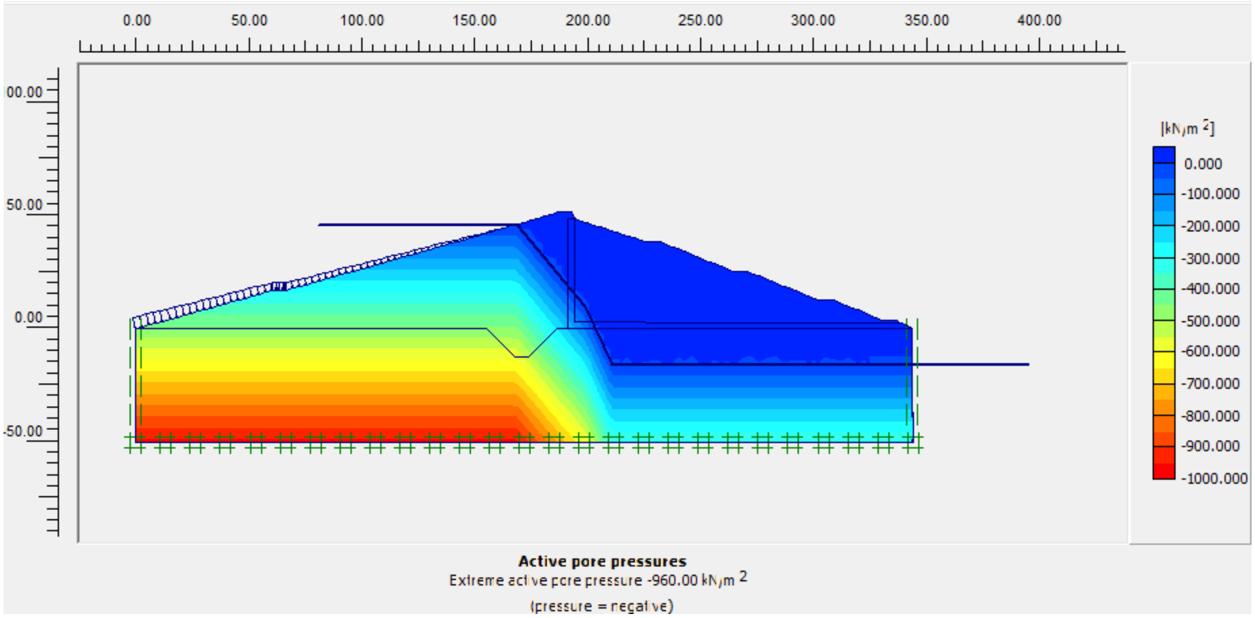

Figure 5.10 Active pore pressure

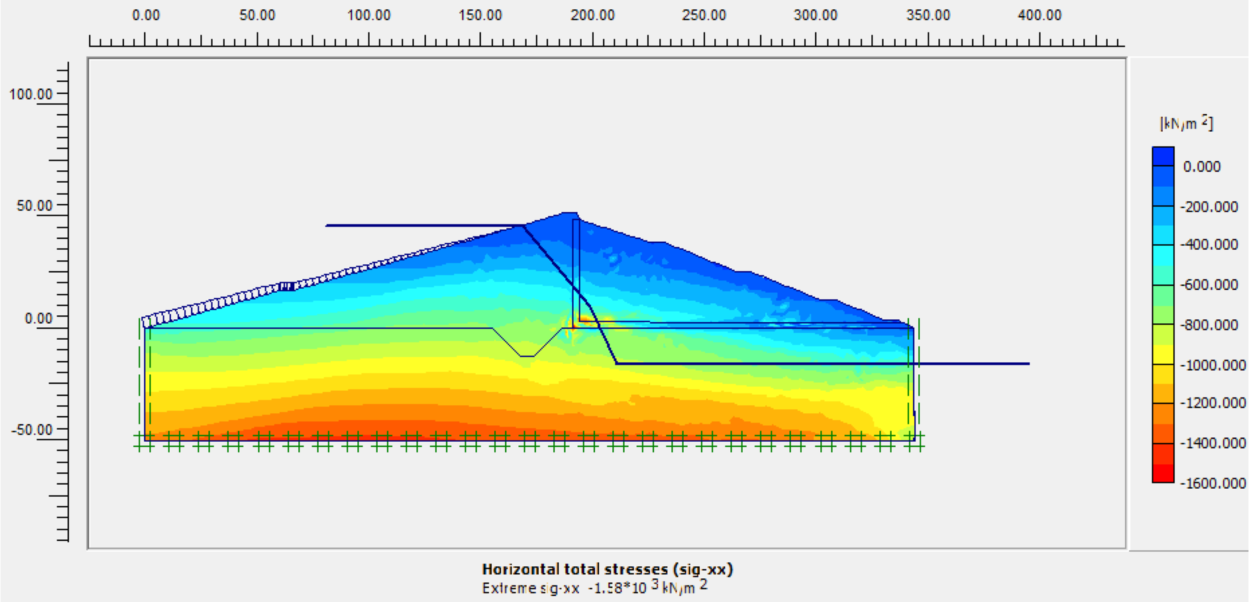

Figure 5.11.Horizontal Total Stress

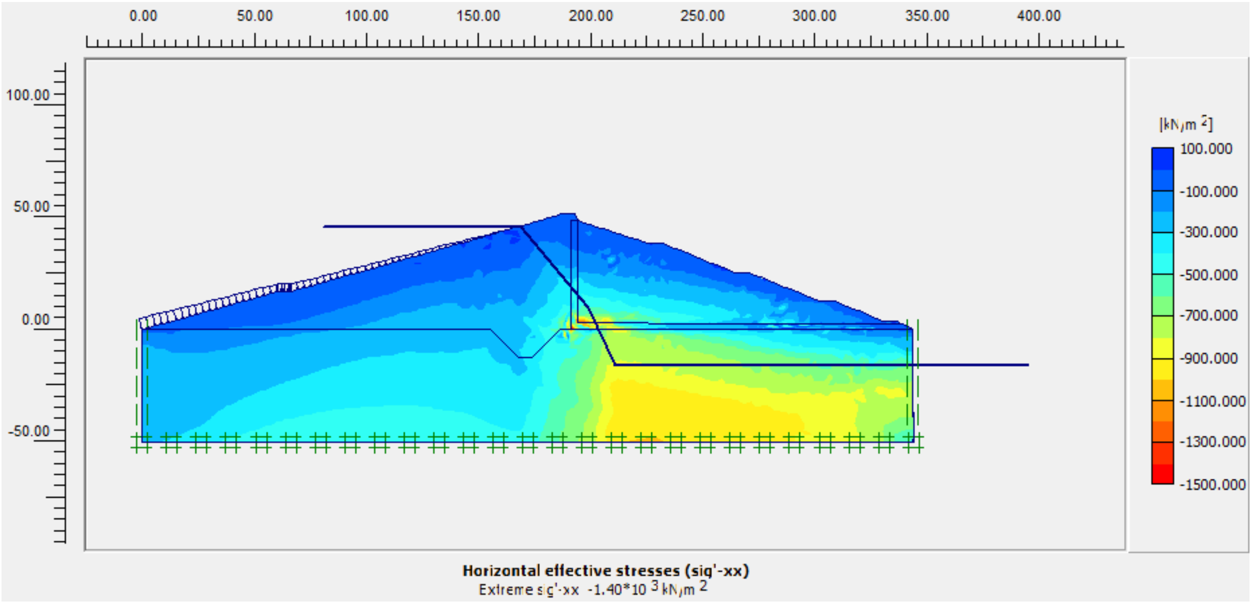

Figure 5.12 Horizontal effective stress.

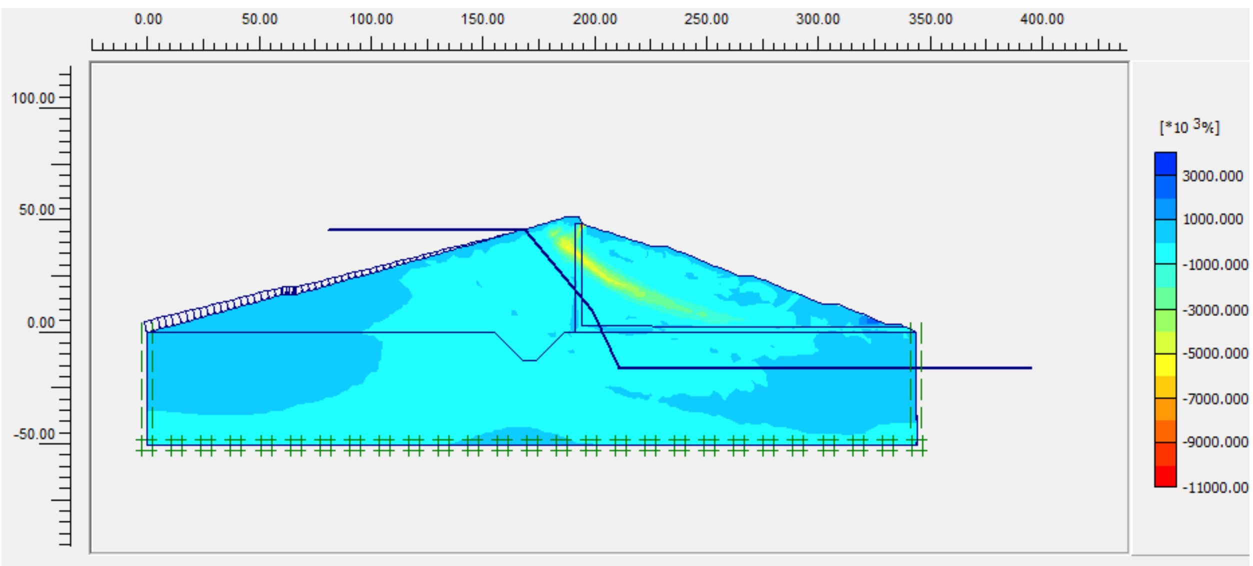

Figure 5.13 Vertical Strain

3.4 SPILLWAY DESIGN:

Discharge of Ogee rested spillway is given as,

$$Q = C.L_e H_e^{3/2}$$

Where, C=Coeffecient of discharge

=2.2 (assuming spillway has high weir i.e. $\frac{h}{H_d} > 1.33$

Le=Effective length of spillway crest=120m

He=Head over the crest including velocity head

Q=Discharge=5836 m^3/s

5836=2.2*120*$H_e^{3/2}$

He=7.87 m

Calculation of velocity head:

Velocity of approach,Va=$\frac{5836}{(120+2.5*9)*(288+10.67)}$ = 0.137 m/s

Velocity head,Ha= $\frac{V_a^2}{2g}$ = 9.56*10^{-4} m

Thus,velocity head is very small and hence can be neglecteed.Therefore total head above the crest was found to be 7.87m

Dowstream profile:

The upstream of the spillway was asumed to be vertical and downstream face parabolic.

Using WES formula,the downstream crest profile is given as,

$$x^{1.85} = 2 * H_d^{0.85} * y$$

Therefore,y=$x^{1.85}$/11.55

The downstream face slope was assumed to be 0.7H:1V

$$\frac{dy}{dx} = \frac{1}{0.7}$$

Therefore ,x=13.12 m and y= 7.82 m.

The tangent point is at (13.12,7.82)

Table. 5.6 Various coordinates of downstream profile.

x	y
1	0.08658
2	0.312121
3	0.660834
4	1.125198
5	1.700249
6	2.382308
7	3.168468
8	4.056341
9	5.043902
10	6.129401
11	7.311298
12	8.588223
13	9.958942
13.12	10.12968

Upstream profile:

Y=$\frac{0.724(x+.27H_d)^{1.85}}{H_d}$ + 0.126H_d-0.4315$H_d{}^{0.375}$(x + $0.27H_d)^{0.625}$

Where x=-0.27H_d= 2.12

Table 5.7 Various coordinates of upstream profile.

x	y
-0.5	0.04943
-1	0.099253
-1.5	0.332976
-2	0.738708
-2.12	0.957947

Final profile was drawn in graph by using the coordinate of upstream and downstream and was extended to the base of the dam to give complete spillway profile.

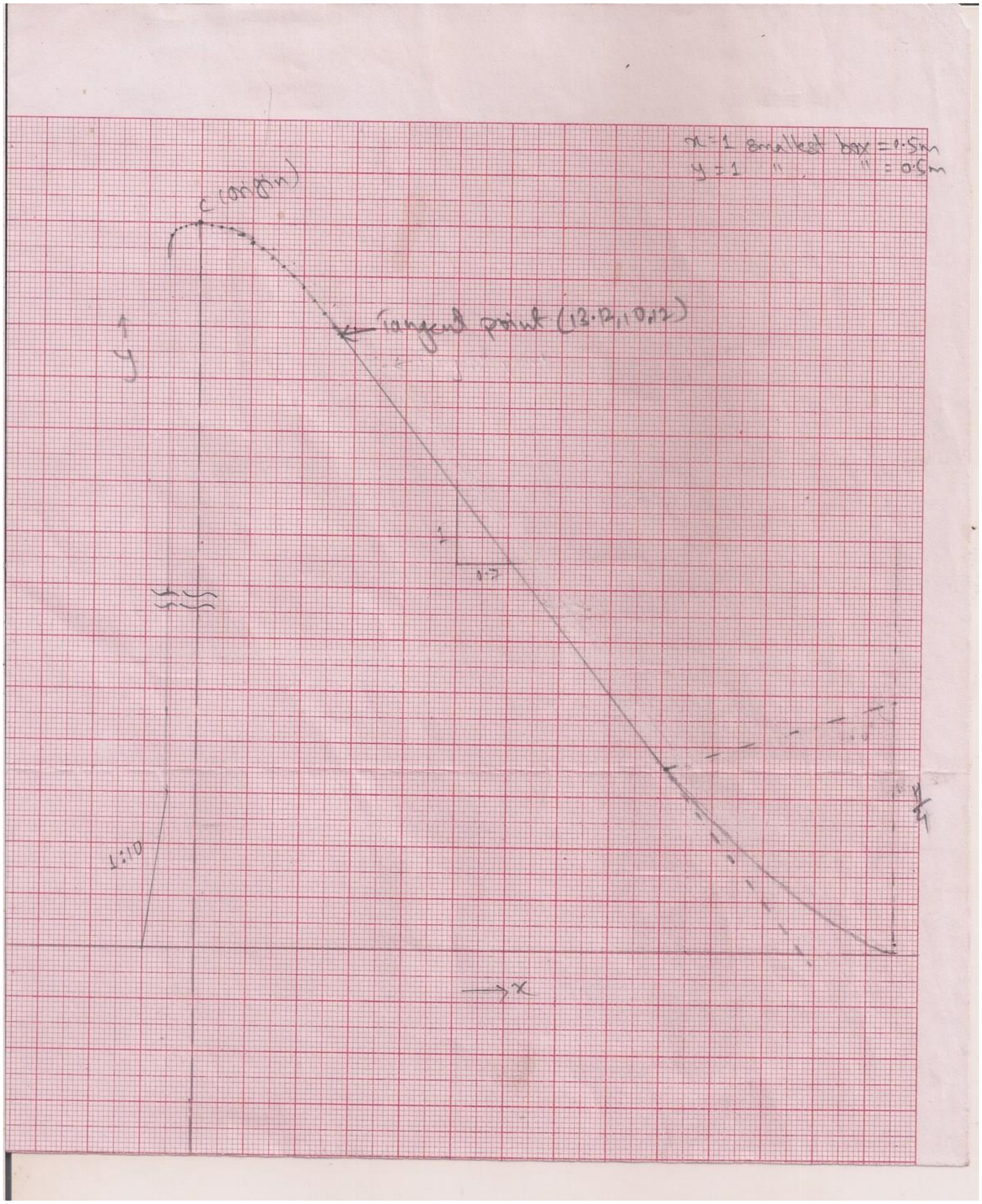

Figure 5.14 Profile of Spillway

CHAPTER 6

CONCLUSIONS

The dam constructed when analysed using PLAXIS gave the safety factor of 1.33 and hence the dam was found to safe against over all stability. From this paper it can be concluded that for a design of any dam, hydrological features must be properly studied before designing to ensure the safety and PLAXIS softwarecan be used for the accurate analysis any Earth dam.

REFERENCES

[1] George H. Hargreaves; Gary P. Merkley, *Irrigation Fundamentals*, Water Resources Publications, LLC, 1998, pp. 2.

[2] Duo, Esther, and Pande,Rohini,Draft :July 2005, "*Dams.*"

[3] Singh V. P.,*Dam Breach Modelling Technology*,Kluwer academic publishers,pg 88-89.

[4]Patra, K.C., Hydrology and Water Resources Engineering, 2012, Second Edition,Narosa Publication, pp. 334.

[5] Snyder, F. F. 1938. Synthetic Unit-Graphs. *Transactions, American Geophysical Union,* **19**, 447-454.

[6] http://www.britannica.com/EBchecked/topic/559952/spillway DOA-15th march 2013

[7] Y.Q. Xu, Unami K. and Kawachi T., January 2003, *Optimal hydraulic design of earth dam cross section using saturated–unsaturated seepage flow model.*

[8] Tien-kuen Hnang, 17 March 1996 "*Stability analysis of an earth dam under steady state seepage*"

[9] Abolfazl Nazari Giglou, Taher Nazari Giglou and Afshar Minaei, 2013, "*Seepage through Earth Dam*"

[10] Rasul Daneshfaraz1, Shabnam Vakili, Mahdi Majedi-Asl and Mohammad Rostami, 2012, "*Numerical Investigation of Upstream Face Slope and Curvature of Ogee Spillway on Flow Pattern*", Journal of Environmental Science and Engineering.

[11] Garg, S.K., Irrigation Engineering and Hydraulic Structures(2011), 24th edition, Khanna Publishers.

[12] IS 10635 : 1993 Freeboard requirements in embankment dams – Guidelines

[13] IS 8826 : 1978 Guidelines for design of large earth and rockfill dams